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The Holometer: A Measurement of Planck Scale Quantum Geometry

STEPHAN MEYER, University of Chicago

Direct experiments show that light and matter obey fundamental quantum principles such as nonlocality, superposition and entanglement. On the other hand, standard, experimentally verified particle theory generally assumes that space-time itself obeys classical determinism and locality – an approximation that cannot be reconciled with quantum matter and general relativity at intervals shorter than the Planck scale, or with the theory of black holes. These suggest that geometry has nonlocal quantum states and finite, holographic information content. The hints of new Planck scale physics open up a new experimental path: in some theories of quantum geometry, new degrees of freedom cause fluctuations in position with detectable, uniquely quantum correlations. We are developing an experiment called the Fermilab Holometer, a correlated pair of high-bandwidth Michelson interferometers. It is the first, and at present unique experiment designed to prepare and measure a coherent quantum state of position over an extended region in space. The sensitivity to transverse position noise, expressed in spectral density units, is smaller than a Planck time. When operating at its design noise limit, it will either detect or rule out some candidate forms of holographic quantum geometry.